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THE ELECTRICAL CONDUCTIVITY PROPERTIES OF FERROELECTRIC NIOBIUM DOPED $LITAO_3$ (LNT) THIN FILMS

AAM HAMDANI[1,*], MUMU KOMARO[1], IRZAMAN[2]

[1] Department of Mechanical Engineering Education, Universitas Pendidikan Indonesia
Jl. Dr. Setiabudhi No. 229, Bandung, Indonesia
[2] Department of Physics, Bogor Agricultural University (IPB University),
Jl. Darmaga, Bogor, Indonesia
*Corresponding Author: aam_hamdani@upi.edu

Abstract

Electrical conductivity is a measure of the ability of a material to conduct electric current. If an electric potential difference is placed at the ends of a conductor, moving charges will move, producing an electric current. The utilization of this electrical conductivity includes ferroelectric materials such as $LiTaO_3$ (LNT) as semiconductors. The purpose of this study is to determine the electrical conductivity of LNT ferroelectric material. With the knowledge of these properties, it will be easy to utilize this thin film layer on a variety of uses. The research method used in this study is laboratory-scale research. The thin films were fabricated by the chemical solution deposition (CSD) and spin coating method, with 1.00 M precursor and spinning speed of 3000 rpm for 30 seconds. The post-deposition annealing of the 9 films were carried out $LiTaO_3$ without niobium (LNT 0%) annealing 850^{O}C, LNT 0% annealing 900^{O}C, LNT 0% annealing 950^{O}C, LNT 0% annealing 1000^{O}C, LNT 2% annealing 850^{O}C, LNT 2% annealing 900^{O}C, LNT 2% annealing 950^{O}C, LNT 2% annealing 1000^{O}C, for 15 hours in oxygen gas atmosphere, respectively. The resistance and electrical conductivity of the grown thin films are characterized by 10 W, 20W, 40W, 60W, 80W and 100W lamps. The electrical conductivity of the grown thin films LNT is due to a semiconductor. The results showed that resistance and electrical conductivity of the thin film have strong correlation to the annealing temperature.

Keywords: Electrical conductivity, Ferroelectric, LNT, Dopant niobium, CSD.

1. Introduction

Perovskite structure $LiTaO_3$, lithium-ion (Li2 +) is located at the end of the ribs cube, titanium ions (Ta4 +) are located on the diagonal, and the oxygen ions placed on the diagonal of the cube. The addition of niobium to $LiTaO_3$ (LNT) will produce the materials ferroelectric/pyroelectric. It is like n-type semiconductor (donor doping) because niobium ions (Nb5 +) will occupy the position of tantalum ions (Ta4 +), which means that the structure has negative ions (n-type) surplus called soft dopant or dopant [1]. Soft dopant ions can produce material that is more ferroelectric soft, elastic similar to higher conductivity. The nature of a lower coercive field, a mechanical quality factor, and the electricity quality are lower [1, 2].

Figure 1 describes the situation of donor dopant playing a vital role in the formation of empty space at the position A (Li2 +) of the perovskite structure due to the electrostatic process and resulting in Li-ion that cannot easily jump into a vacant space for oxygen ionic inhibited [1].

One of the characteristics of the connection formed in a PN photovoltaic solar cells is the electrical conductivity properties testing and test thin film photovoltaic currents. Based on the value of the electrical conductivity of a material, it can be divided into three parts namely conductors, semiconductors and insulators. Figure 2 shows an insulating material in the interval score 10-18 S/m to 10-8 S/m; the semiconductor is in the interval score 10-8 S/m to 103 S/m, and the conductor is in the interval value of 103 S/m up to 108 S/m [3].

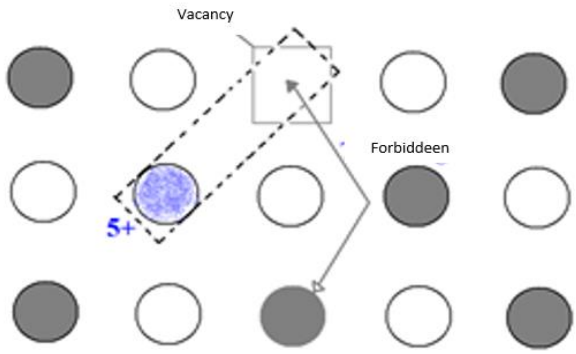

Fig. 1. Donor dopant [1].

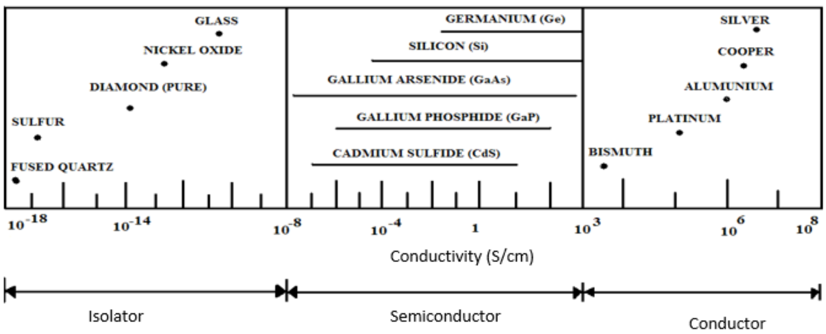

Fig. 2. Differentiation of materials based on electrical conductivity [3].

The results showed that Itskovsky [4] has succeeded in making solar cells triglycine infrared ferroelectric sulfate, $LiTaO_3$, $NaNO_2$, and the chopper wheel design with the difference between the resonance frequency arm section (FR1) and a resonance frequency of the driving section (fr2) by 10% in instruments of pyroelectric flow measuring solar cells. Meanwhile, some researchers has successfully assisted ferroelectric current measurement and JFET I / V converter with a characterization of the sensor electrical response time of 2 seconds on the capacitor = 40 pF, and resistance = 50 ΩG and frequency response 3 dB above its cut-off frequency [5-7].

In this research, a $LiTaO_3$ thin film will be made without adding elements and adding niobium. Then annealing at various temperatures to determine its effect on electrical conductivity

The purpose of this study was to determine the electrical conductivity of LNT ferroelectric material. With the knowledge of these properties, it will be easy to utilize this thin film layer on a variety of uses.

The research method used in the study was laboratory-scale research. The fabrication of the thin films is by using the chemical solution deposition (CSD) and a spin coating method, with a 1.00 M precursor and a spinning speed of 3000 rpm for 30 seconds. The post-deposition annealing of the 9 films were carried out $LiTaO_3$ without niobium (LNT 0%) annealing 850 ^{O}C, LNT 0% annealing 900 ^{O}C, LNT 0% annealing 950 ^{O}C, LNT 0% annealing 1000 ^{O}C, LNT 2% annealing 850 ^{O}C, LNT 2% annealing 900 ^{O}C, LNT 2% annealing 950 ^{O}C, LNT 2% annealing 1000 ^{O}C, for 15 hours in oxygen gas atmosphere, respectively.

2. Methods

The equipment's used in this study were a scale Sartonius BL 6100 model, a set of reactors spin coating, mortar, pipettes, measuring cup, glass cup, test tube, iron, plastic tweezers, scissors, stopwatch, spatulas, rubber gloves, masks, petritis, glass beaker, air compressors, lamps, IC 741, resistors, potentiometers, pikoohmmeter, microvoltmeter, multimeters, battery, cables, and the bread-board.

Materials used in this study were Lithium acetate (99%), Lanthanum isopropoxide (99%), Nb_2O_5 Niobium pentaoxide (99.9%) and solvent 2-methoxyethanol [$H_3COOCH_2CH_2OH$, 99%], the silicon substrate (100) n-type, aquadest, methanol, acetone, and aluminum foil.

In the research, it was made by the method $LiTaO_3$ chemical solution deposition (CSD). All materials were crushed during the first 3 hours to obtain a fine grain. Then, these ingredients were mixed and shaken manually for 1 hour (the mixture commonly called precursor). Next, the precursor was heated on the surface of iron at a ± 120 ^{O}C temperature for 5 minutes, so the ingredients will be mixed evenly. Afterward, the precursor was filtered with filter paper to obtain a more homogeneous solution [2, 8].

A substrate was placed on the spin coating reactor that had been given an adhesive. The center of the substrate was added by 2 drops of Si (100) n-type precursor solution. Then, the reactor activated a spin coating at 3000 rpm for 30 seconds. The Si (100) n-type substrate was processed on the heated ironing surface for an hour at ± 120 ^{O}C temperature. The substrate is prepared for the next step of annealing.

3. Results and Discussion

Materials that had been formed through the annealing process in the MFM structure measured its resistance. The resistance of a material depends on the length L and inversely proportional to the value of electrical conductivity and cross-sectional area A according to equation 1 [7]:

$$R = \frac{L}{\sigma A} \tag{1}$$

Informing a power conductivity material depends on temperature. Electrical conductivity is one of the empirical constants of every material and different values for each material [7].

Thin film resistance measurement is done by using LNT electronic circuit Op-Amp, as shown in Fig. 3. Measured resistance value, derived from the conversion of voltage values by using equation 2 [1].

$$R_{ft} = \frac{V_{ft} R_1}{V_{total} - V_{ft}} \tag{2}$$

where R_{ft} is a thin film resistance, V_{ft} is a thin film voltage on the multimeter measured the voltage divided by the amplifier (this study using a 10 times voltage amplifier), V_t is the total voltage (9 V voltage plus the voltage thin film), and R_1 is the used resistance.

The calculation of the conductivity value of thin film was based on the measurement of resistance values by using equation 1. In this experiment, the value of LNT thin film length L = 10^{-3} m and 4-section area values A = 1:35 10-9 m^2. A thick thin film of 0675 µm was used [8]. The obtained calculation results of the conductivity value of LNT thin film was classified into conductor, semiconductor, or insulator (see Fig. 2).

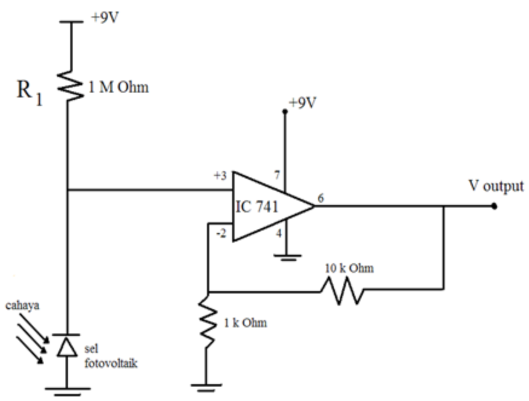

Fig. 3. Electronic circuits Op-Amp resistance measurement [1].

Measurement scale of LNT thin film resistance was done by illuminating the cells with varied light power of 10, 20, 40, 60, 80, and 100 W lamps and connecting the othmic aluminum, which was put above $LiTaO_3$ and LNT 2% which was associated with Op-Amp circuit applications: resistance.

On the Op-Amp circuit applications, the reference resistance of 10 kΩ and 1 kΩ input resistance were utilized. The used barriers are not too big, and this is done in order to reduce signal noise that can affect the value of output produced by the circuit.

Based on a series of 3 images, the result of the output signal from this circuit is the magnitude 3 voltage, but the equation is the conversion of its voltage to resistance and on the basis of equality gained 2 electrical conductivities.

Figures 4 and 5 were the result of resistance and conductivity measurements of thin films and $LiTaO_3$-LNT structured ferroelectric metal-metal. Figures 4 and 5 were obtained from the conductivity value of $LiTaO_3$ thin films and used LNT has a minimum order of 30.00 S/m to 31.25 S/m, so the film used is a semiconductor material. These results can be seen as the influence of annealing temperature on thin-film resistance value. When the photovoltaic cells at 40 watts of lighting conditions seem to increase the value of electrical conductivity at 60 watts. However, the increase in the value of the resistance makes a decrease in electrical conductivity. In the illumination conditions of 80 and 100 watts, the electrical conductivity values back up.

The influence of temperature on electrical conductivity values (see Fig. 4) has a proportional relationship meaning there is an increase in annealing temperature caused by an increase in electrical conductivity values. This happens due to the increase in annealing temperature which causes increase evaporation of the thin film layer so that the thin film thickness is reduced and the defect structure decreases. The increase in conductivity due to electron flow increases because of scattering by crystal defects, which tend to decrease [9].

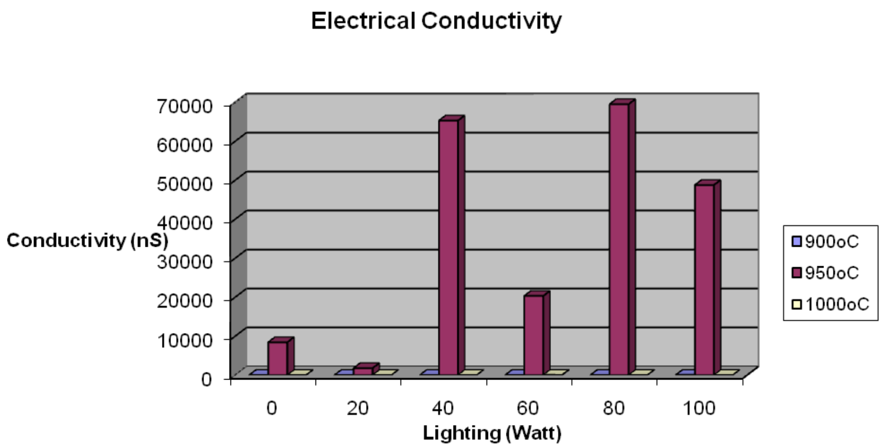

Fig. 4. Conductivity measurement of thin film ($LiTaO_3$).

When photovoltaic cells were at 40-watt lighting conditions, the value of electrical conductivity is greater at 60 W lighting. However, an increase in the resistance value causes the electrical conductivity to decrease. This also applies to 80-watt and 100-watt lighting conditions.

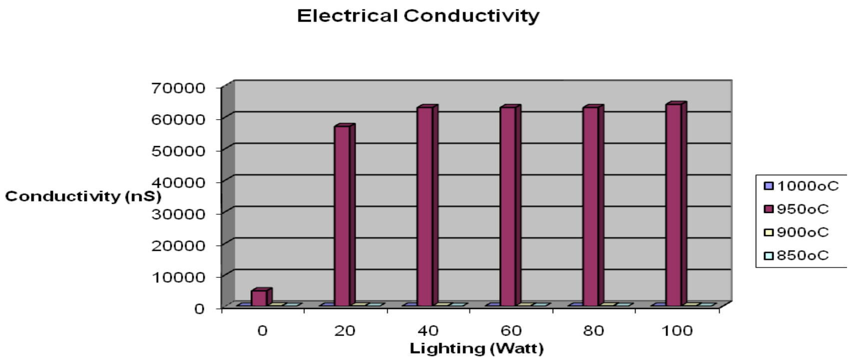

Fig. 5. Conductivity measurement of niobium dopped $LiTaO_3$ thin film.

For $LiTaO_3$ that niobium holds, generally, they have the same electrical conductivity value. This equal to electrical conductivity value occurs in lighting tests of 20 W to 100 W. This is because the addition of the niobium element causing scattering by crystal defects that do not exist. As a result, electrical conductivity increases. The measurements clearly indicate that light-induced transport properties can be entirely controlled by dopants in suitable valence states [10, 11]. This support is useful for developing and improving the quality and function of the application.

4. Conclusion

This research has successfully grown $LiTaO_3$ thin film on the LNT substrate Si (100) n-type by using the method of chemical solution deposition (CSD). $LiTaO_3$ thin film and LNT are semiconductor materials that have an electrical conductivity value of about 30 S /cm. After a supporting result, a new semiconductor is found, namely an extrinsic (impure) semiconductor, which has two types, namely n-type semiconductor and p-type semiconductor. This extrinsic semiconductor is used as the basic material of electronics such as diodes, transistors, integrated circuits and so on.

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